REAL-TIME TEMPERATURE MONITORING SYSTEM USING MATLAB

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ABSTRACT

This project involves the implement of temperature sensor for industrial related applications in real-time. The purpose of this project is to monitor and measure the temperature level of liquid or water. This project not only involves the development of the Matlab software for monitoring purpose but also includes the development of the sensor system. The sensor that will be use is the temperature sensor which can measure the temperature of liquid or water and with suitable temperature range. The sensor system should have DAQ capabilities using DAQ cards which available in the laboratory. Matlab Programming language will be use to develop interface for the sensor system. GUI (Graphical User Interface) is consists of buttons that user easily can view the temperature will be creating using Matlab software which is to monitor the temperature. The value of the temperature will be detecting automatically base on the system and transfer the value using serial USB port to the computer. Matlab will collect and record the data in graph format. In this system, the developed sensor should capable to measure temperature in real-time. The system also should capable to store and retrieve data for further analysis. The sensor system will be tested in the laboratory environment and/or in real industrial applications.

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LIST OF ABBREVIATIONS

A/D	Analog to Digital
D/A	Digital to Analog
DAQ	Data Acquisition System
GUI	Graphical User Interface
RTD	Resistance Temperature Detector
PC	Personal Computer
PTC	Positive Temperature Coefficient
USB	Universal Serial Bus
VB	Visual Basic

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The meaning of temperature is the changes of temperature or physical state such as solid to liquid, liquid to gas and one crystalline form to another. Temperature also the changes level of heat or cold of a material or device [12]. Temperature monitoring system is the process of monitor the temperature changes in order to prevent from failure of operation or damage of a system. This system already applies in industry such as automotive industries, air conditioning, power plant and other industries such as HVAC system, heaters and boilers.

Sensor is the sensing device that can detect or measure a physical quantity such as temperature, pressure, force and displacement. Sensor is the best device in this project system which is to measure the temperature. Sensor has two types which contact sensor and non-contact sensor. The non-contact sensor is for measuring the surface that cannot be touched during the measurement process such as plastic, silicon and glass. Contact temperature sensors measure it own temperature [4]. Examples of contact sensor are thermocouple, RTD and thermistor.

This project system is run and collect the data in real-time which using a software that can analyze the data in real-time. Before the software can analyze the data, must have some device that can grab the data from sensor and convert the data into a data that PC (personal computer) can understand or read which, the device is data acquisition system (DAQ). Function of DAQ is to convert the analog signal to digital signal (which can understand by PC).

The aim of this project is to develop sensor system that capable measuring and monitor the temperature changes in real-time. To perform real-time monitoring, Matlab software is use in this project and other software can be use such as Labview and Visual Basic (VB). Matlab, Labview and VB have the same function which can use it to display the output or key-in the input value or parameter. This software still have differences between each other which in Labview, the block diagram is link with GUI model and it compatible with National Instruments (NI) device. While in Matlab, simulink block diagram and GUI model is two different types of way in using this software and not link each other.

1.2 PROBLEM STATEMENT

The problem statement in this project is the measurement and monitoring of temperature in industrial liquid and material very important because it can affect the result in the final product. The Graphical User Interface (GUI) is developing using Matlab. With this GUI, user can monitor the change of temperature through user own personal computer (PC).

1.3 OBJECTIVE

The objective of the project is:

i. To design GUI using Matlab for monitoring the change of temperature

ii. To design and build a system with suitable range and precision of the temperature sensor

iii. To develop sensor system which capable to monitoring temperature in real-time

1.4 SCOPES OF PROJECT

Several scope of project is:

i. The hardware part of temperature system will be designed and development

ii. The software for GUI and data analysis will be develop using Matlab

iii. The working sensor system will be tested in related industrial application

iv. The sensor should capable to monitor temperature in real-time

1.5 OUTLINED THESIS

This thesis consists of five chapters which is the first chapter is the Introduction that discuss about the background of this project, objectives, scope of this project which are for the overall summary of works. The second chapter will discuss about several theory and literature reviews that had been done in this project. In this chapter, the basic theory of sensor, type of sensor and the function of DAQ had been discussed. The process flow of the project will be discussed in Chapter 3 which is the methodology part. The second last chapter is the results and discussions part which consists of data from GUI. Finally, the last chapter which is Chapter 5 will concluded overall of the project and future recommendation that can improve this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter which is Chapter 2 will explain about the literature review that related to temperature monitoring system which the fact or researcher idea were taken from journals or articles related to this project. In this part consists of the types of sensor, seeback effect, DAQ and the software.

2.2 SEEBACK EFFECT

The first discovered the phenomenon of Seeback Effect is Thomas Johann Seeback in year 1800s. The voltage difference occurs between two substances when there is temperature difference between two not similar electrical conductors or semiconductors. This phenomenon is called the Seeback Effect. Seeback Effect produced small voltages which is only a few microvolts per Kelvin of temperature difference at the junction. If a large temperature difference is maintained, small-scale electrical power can be provided by the large arrays of Seeback Effect devices [10].

To produce a large voltage as studied in Electrical Circuit subject, in a series circuit, the output voltage is the total of load voltage that will give an increase voltage which that why the effect is pictured in Figure 2.1 below. The behaviour of thermocouple is generated from the Seeback Effect.

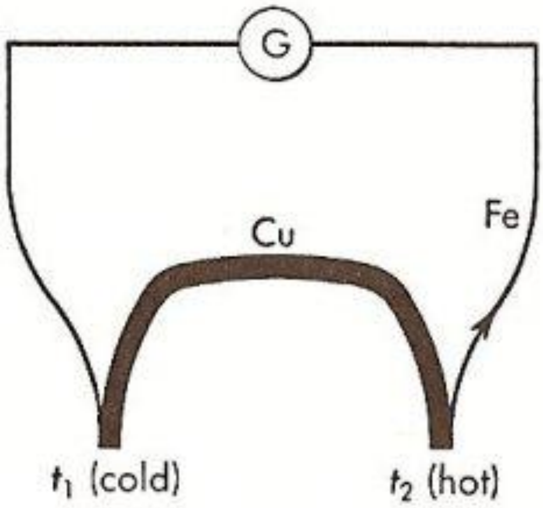


Figure 2.1: Seeback Effect

The performance of thermocouple is based on the material property which is the Seeback Coefficient. The material property and the Seeback Voltage per unit temperature is a Seeback Coefficient. An opposing electric field is created because of there is net diffusion of electrons from hot end to the cold end which is from the temperature gradient that exist over a piece of electrically conductive wire. This situation will cause a voltage over the wire which is called as Seeback Voltage. Different metals may have different signs of Seeback Coefficient and the metal Seeback Coefficient is such as Table 2.1 below [3].

Data for the materials is sensitive which is prone to variation. The combination of highest plus and minus Seeback Coefficients is the best choice for a thermocouple. The reason why thermocouple is in metallic is because metals cannot be fabricated in the form of thin and robust wires [3]. Table 2.2 shows the combined Seeback Coefficient for standard thermocouple.

Table 2.1: Seeback Coefficient for some metals

Metals	Seebeck Coefficient
	μV/K
Antimony	47
Nichrome	25
Molybdenum	10
Cadmium	7.5
Tungsten	7.5
Gold	6.5
Silver	6.5
Copper	6.5
Rhodium	6.0
Tantalum	4.5
Lead	4.0
Aluminum	3.5
Carbon	3.0
Mercury	0.6
Platinum	0
Sodium	-2.0
Potassium	-9.0
Nickel	-15
Constantan	-35
Bismuth	-72

Table 2.2: Seeback Coefficients for Standard Thermocouples

Type	Couples	Seebeck Coefficient
		μV/K
E	Chromel-Constantan	60
J	Iron-Constantan	51
T	Copper-Constantan	40
K	Chromel-Alumel	40
N	Nicrosil-Nisil	38
S	Pt (10% Rh)-Pt	11
B	Pt (30% Rh)-Pt (6% Rh)	8
R	Pt (13% Rh)-Pt	12

2.3 TEMPERATURE SENSOR

Sensor is the sensing device or a detector that can detect or measure a physical quantity such as temperature, pressure, force and displacement. Sensor also known as an element that changes to an electrical signal from some physical parameter. Output signal from sensor can be measured and recorded but must be converted the physical condition into an information that control system can understand [11]. This project is to measure temperature which sensor is the best device for this situation.

There are two types of sensor which is contact sensor and non-contact sensor. The non-contact sensor is for measuring the surface that cannot be touched during the measurement process such as plastic, silicon and glass. Contact temperature sensors measure it own temperature [4]. Examples of contact sensor are thermocouple, RTD, thermistor and semiconductor device.

2.3.1 THERMOCOUPLE

Temperature monitoring system is widely use in industry which is very important nowadays that will involve such a losses if not monitor it. To develop a system that will monitor and measure a temperature is by using the temperature sensor. Thermocouple is one of the temperature sensors which are inexpensive and versatile devices. Thermocouple has eight types of it, which is B type, E type, J type, K type, N type, R type, S type and T type. Each of these has their own characteristic. Table 2.3 show the difference between eight types of thermocouples.

Table 2.3: Difference of thermocouple types

Thermocouple Type	**Overall Range**	**Typical Accuracy***	**Comments**
Type B Platinum(+) Rhodium (-)	100 to 1800	5 °C (at 1000°C)	-For high temperature measurements. -Give same output at 0 °C and 42 °C. -Useless below 50 °C because give same output.
Type E Chromel (+)	-200 to 900	1.7 °C	-has high output (68 µV/°C) makes it well suited to low temperature (cryogenic) use.

Thermocouple Type	Overall Range	Typical Accuracy*	Comments
Constantan (-)			-Another property is non-magnetic.
Type J Iron (+)/ Constantan (-)	-40 to 760	2.2 °C	-Limited range -less popular than type K. -should not be used above 760°C as an abrupt magnetic transformation will cause permanent decalibration.
Type K Chromel (+) Alumel (-)	-200 to 1300	2.2 °C	-'general purpose' thermocouple. -low cost and popular. Sensitivity is approx 41 µV/°C. Use type K unless you have a good reason not to.
Type N Nicrosil (+) Nisil (-)	-200 to 1300	2.2 °C	-High stability and resistance to high temperature oxidation -high temperature measurements without the cost of platinum (B,R,S) types. - 'improved' type K and becoming popular.
Type R (Platinum 13% Rhodium (+) / Platinum (-))	-50 to 1760	1.5 °C	-high temperature measurements up to 1600 °C. - Low sensitivity (10 µV/°C) and high cost - Unsuitable for general purpose use.
Type S Platinum 10% Rhodium (+) Platinum (-)	-50 to 1760	1.5 °C	-high temperature measurements up to 1600 °C. - Low sensitivity (10 µV/°C) and high cost -unsuitable for general purpose use. -used as the standard of calibration for the melting point of gold (1064.43 °C) due to high stability
Type T Copper (+) Constantan (-)	-200 to 400	1 °C	-Best accuracy of common thermocouples -used for food monitoring and environmental applications.

Among all type of thermocouple, K type is the most popular and mostly use. The range for J type is between -40 to 760°C which mean that this type of thermocouple is the lower ranges of temperature and can use it for small industries and small temperature usage application. For example, a K type is the most popular thermocouple at 300 °C will produce 12.2 mV. This voltage produced show that thermocouples are self-powered and require no excitation current unlike RTDs and thermistors [15]. Thermocouple will produce it own voltage or in other word is self-powered but it cannot be measure using voltmeter. Thermocouple has the temperature range between -200 to 2000^0C and it relatively a low cost and also versatile.

The thermocouple sensor has a small output voltage in the milivolt range. A monolithic thermocouple amplifier with cold junction compensation (AD595) is used to amplify the output voltage [5]. The basic operation of thermocouple is based on the physical principles if two dissimilar metal wires are joined together at one end and a small voltage difference is generated across two unheated end which is called as thermoelectric emf or also called as Seeback voltage. This phenomenon is known as Seeback effect. This is proved that thermocouple is self-powered. Cold-junction compensation is a signal conditioning technique that employed when using thermocouple for measurement.

Based on Figure 2.2 below, sensing junction and reference junction must be connect each to a different temperature, then the voltage difference can be detected. This voltage different will be zero if the junctions are at the same temperature and will increase as the temperature of one junction relative to the other is changed until a peak is reached [12]. Each wire have different thermoelectric sensitivities or known as Seeback coefficient which mean for every 1°C difference in temperature, the Seeback voltage which it value is same as Seeback coefficient is induced. The relationship between Seeback voltage and temperature is proportional which produce a linear graph only for small changes in temperature which shows in Figure 2.4 [6].

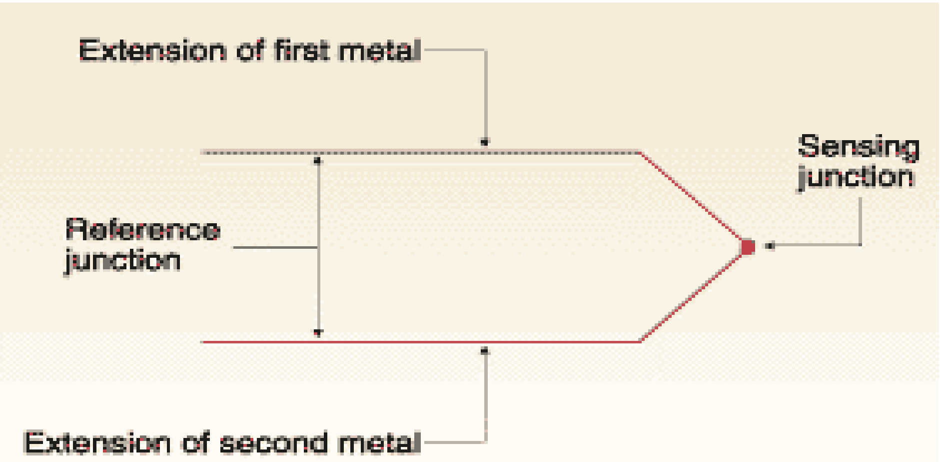


Figure 2.2: Thermocouple construction

Figure 2.3: Temperature Sensor type

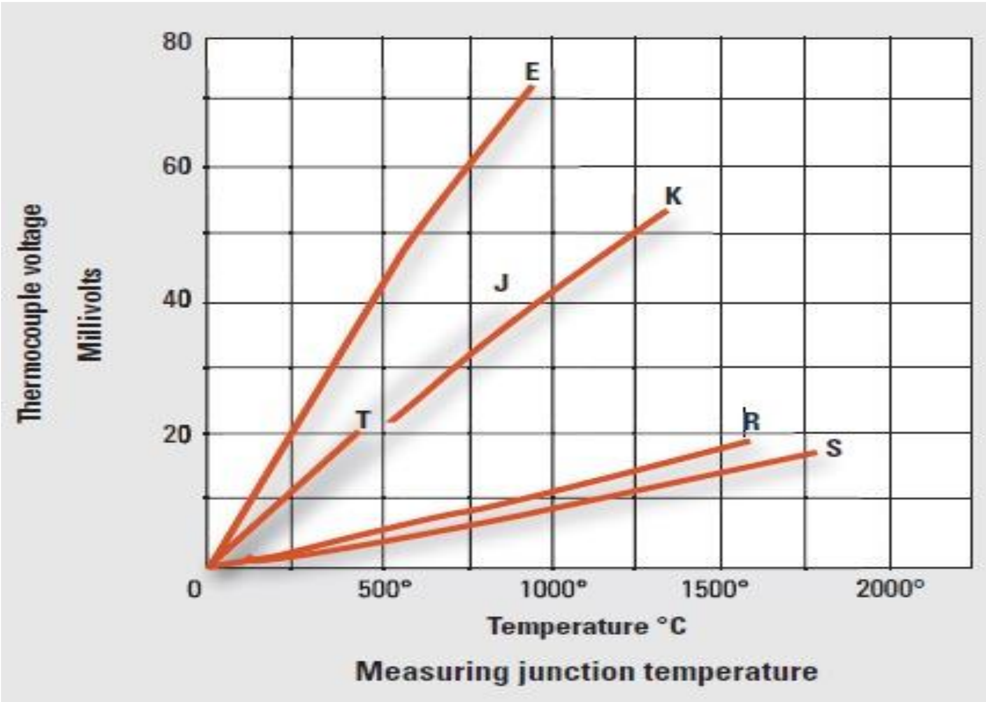


Figure 2.4: The relationship between temperature and Seeback Voltage

2.3.1.1 EXPOSED JUNCTION THERMOCOUPLE

There are three types of thermocouple which one of it is exposed junction type. Such as it name, this type of thermocouple junction or measuring point were exposed to the surrounding environment or without any protection tube and comes out of the tip of the sheath [16]. Protection tube is a tube to protect the element from harsh environments. The most common methods to form the junction are a twist-andweld procedure or butt-welded [1]. The maximum temperature may be lower if the probe sheath diameter is smaller will causes the response faster.

This thermocouple has it limited in use to apply at dry, noncorrosive and non pressurised although have the best response time but lowest radiation error and least conduction error which much better than grounded junction type. Response time is a time constant that required by sensor to reach 63.2% of a step change in temperature. This type of thermocouple is best suited for air measurement and usually for measuring the temperature of gas or solid materials. Measuring tip of this thermocouple need to be seal or cover it with an insulating paint or epoxy to avoid moisture enters into the thermocouple.

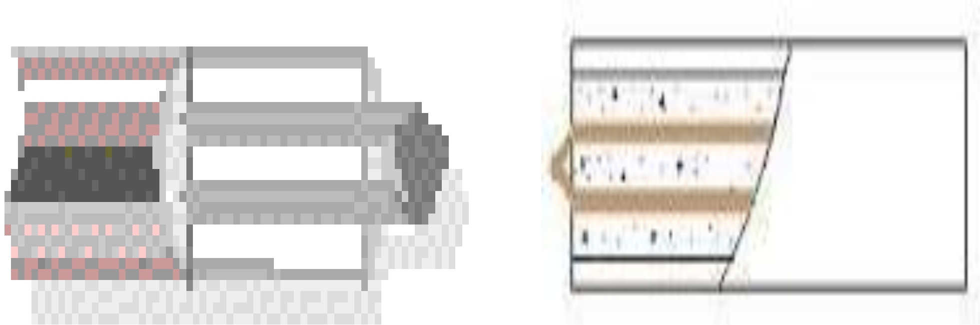


Figure 2.5: Exposed Thermocouple

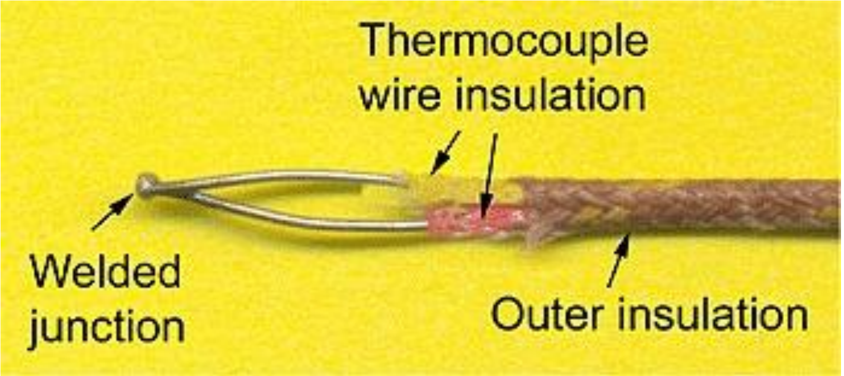


Figure 2.6: Namely parts of exposed thermocouple

2.3.1.2 GROUNDED JUNCTION PROBE THERMOCOUPLE

Another type of thermocouple is the grounded junction probe thermocouple which is different from exposed junction where the wire at the tip is physically welded or melt together to the inside of the probe wall which is referred as the sheath of the probe and allow them to solidify and forming a completely sealed integral junction [1]. Through the probe wall, good heat is transfer from the outside to the thermocouple junction. The common material of the sheath includes stainless steel and Inconel. Cause of broad chemical compatibility, stainless steel is preferred but support lower temperature range than Inconel.

The advantages of the grounded junction are fast response time, more accurate reading at short distance but most vulnerable to electrical ground loops, noise pickup and the possibility that the thermo elements may alloy with the sheath are the disadvantages of this thermocouple [1]. Rather than bending and welding the wires to the tip, it is better to bending and welding to the inside wall of the sheath to achieve fast response time. This thermocouple is more rugged and capable tolerating physical and mechanical abuse [16]. This junction type is for measuring static or flowing corrosive gas and liquid temperatures and also used in high-pressure conditions.

Noise is one of the disadvantages of this type of thermocouple. Noise is the signals that are the same on both wires which can be minimised. To ensure both wires pick up the same noise signal, the cable are twisted together. If there still a remaining noise, used analog to digital converter (ADC) to average out the remaining noise [8].

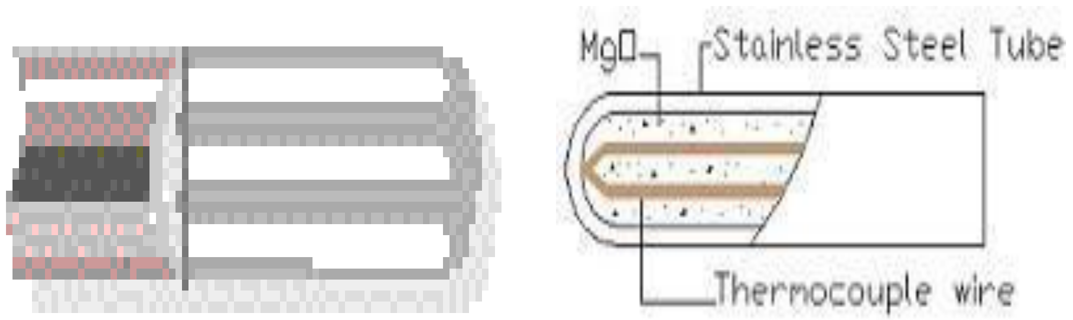
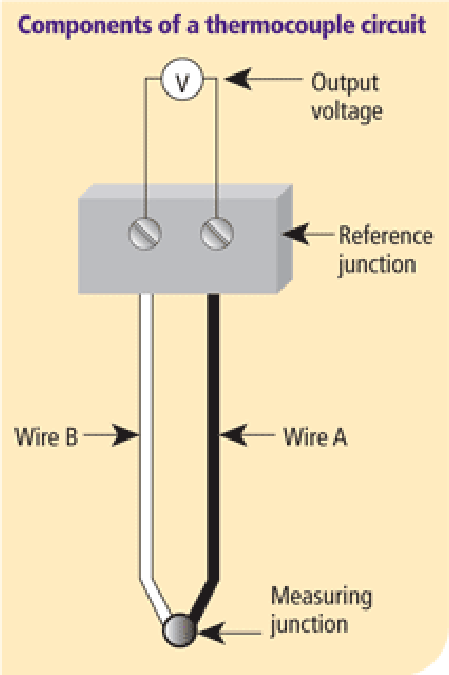
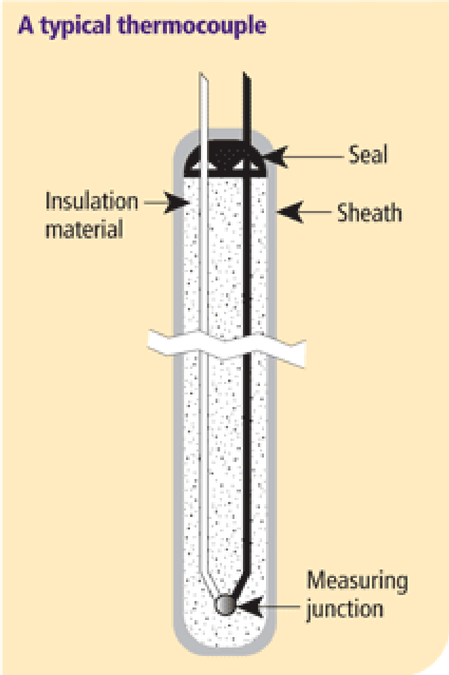


Figure 2.7: Grounded Thermocouple





a) b)

Figure 2.8: a) Components of a thermocouple circuit and b) A typical thermocouple

2.3.2 RESISTANCE TEMPERATURE DETECTOR (RTD)

RTD sensor is stand for Resistance Temperature Detector which is measure changes in resistance that result from changes in temperature which same as the thermistor. The any metal electrical resistance varies according to its temperature which is in the most cases, resistance directly proportional with temperature at a specific rate which has a positive temperature coefficient (PTC). The practical operating range of RTD is between -250 to 850^{0}C and the most RTD used is the Pt100 because it has a resistance of 100Ω at 0^{0}C. RTD is much more costly and slower responding than others sensors but RTD become more accurate and more linear by using a platinum resistance element.

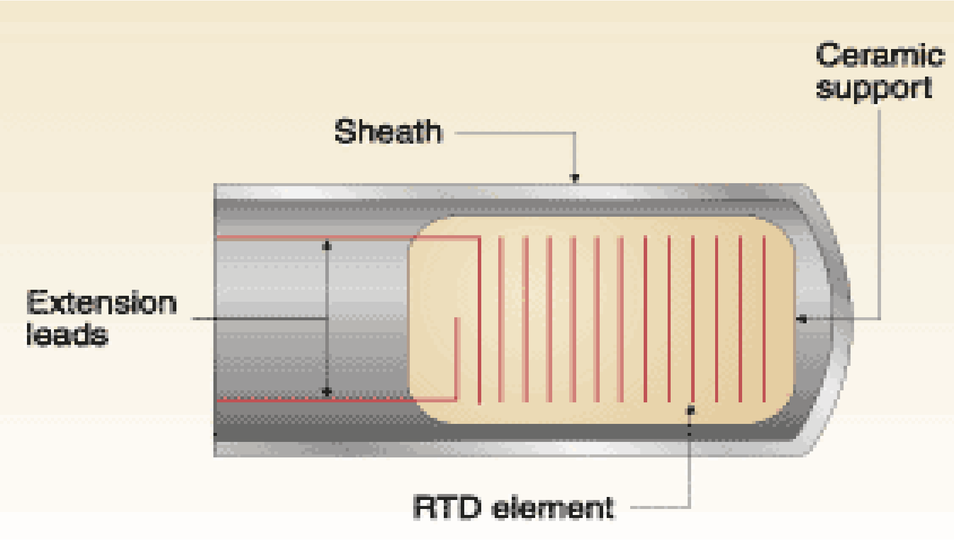


Figure 2.9: RTD Construction

2.3.3 THERMISTOR

Thermistor has a limited temperature range between the previous two sensors which is -100 to 300^{0}C. Thermistor cannot cover this high range and a thermistor cannot stand alone because of lack of standards which means it is often necessary to buy the sensor and measuring equipment together [15]. RTD and Thermistor is the same in terms of heating which is it self-heating and because of that, these both sensors cannot have too large current which can make the sensor damage. The change of temperature of thermistor is so large, so that, thermistor can provide good accuracy and resolution.

2.3.4 SEMICONDUCTOR SENSOR

LM35DZ is the temperature sensor type semiconductor device. This device is linear voltage production and the exchange of temperature is same like other three sensors which are in degree Celcius (^{0}C). LM35DZ can operate between temperature ranging from -55^{0}C to +100^{0}C [7].

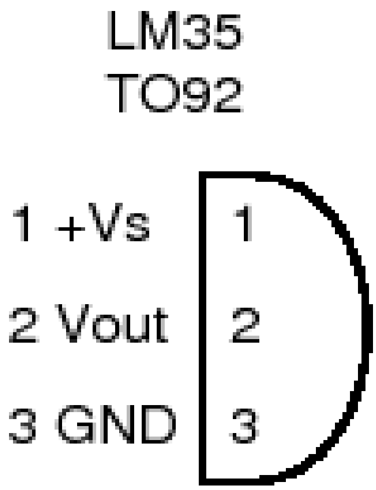


Figure 2.10: Pinout of LM35

Table 2.4: Advantages and Disadvantages of Sensor

	Thermocouple	RTD Sensor	Semiconductor	Thermistor
Advantages	-Self-powered -No self-heating -Low cost -High temperature range -Use for wide temperature range	-Accuracy -Stability -Linearity	-Cheap -Ease to use -More accurate than thermistor -Sealed	-Low to moderate cost -Accuracy -Sensitivity
Disadvantages	-Low accuracy -Low stability -Low output signal -Non-linear output is produced	-Expensive -Self-heating	-Using amplifier circuit	-Low linearity -Self-heating -Cannot standalone